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PHOSPHATE DEPOSITS

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REPORT

ON THE

PHOSPHATE DEPOSITS OF EGYPT

BY

Egypt -

THE GEOLOGICAL SURVEY

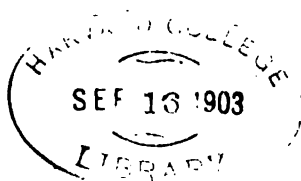
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A REPORT ON THE PHOSPHATE DEPOSITS OF EGYPT.

CHAPTER I.

BONE-BED NEAR QIFT, IN QENA MUDIRIA.

Prior to the formation of the Geological Survey in the summer of 1896, the existence of phosphate-bearing beds, of economic value in the Nile valley or Egypt generally, was entirely unknown. Figari Bey in his description of the beds between Siloë and Edfu mentions an ash-grey sandy breccia with remains of bones, fish-scales, and shell fragments, but makes no statement as to its being likely to be of any commercial value, and other writers on the geology of Egypt are silent on this subject.

It was only in the early part of 1897, while engaged in the examination and mapping of the district on the east bank of the Nile extending from a little to the south of Esna, as far as Qena on the north, with the object of reporting on the extent and value of the "Tafla," a nitrate-bearing clay, that the writer discovered the existence of bone-beds, some of which looked exceedingly promising. The first of these was found in a small hill about 18·5 kilometres south of Esna, where three thin beds occurred:—

- (Top) Oyster bed (with a layer of conglomerate in the middle containing bone fragments, 0·28 metre), total thickness 3·3 metres.
- (2) Thin layer of fissile limestone with siliceous concretions.
- (3) Bone-bed 0·125 metres.
- (4) Hard limestone 0·8 metres.
- (5) Bone-bed with fish teeth, etc., with layer of shells at base 0·28 metres (probably Figari Bey's bed).

Sandy shales underneath.

Samples of these were examined in the Khedivial Laboratory, but were found to be too poor in phosphoric acid to warrant their being worked. From this point northward until east of Qift, no other signs of phosphate-bearing beds were met with, until during an examination of a small plateau mainly composed of shales similar to those worked for Tafla, a brownish bed of about 1 metre thick, showing on its fractured

surface numerous fish vertebræ, teeth, and what are probably coprolites, was met with. After ascertaining that it covered a respectable area, and was fairly constant in thickness, a preliminary report, accompanied by a sample of this bed, was sent in to the Geological Office; and after an analysis had been made and it was found that there was a fair percentage of phosphate present, a fuller report was sent in.

Since then the same bed has been discovered further north, to the east of Qena, in Wadi Hammama, on the east side of the Red Sea hills, in the Duwi range on the Qena-Qosseir road, at the confluence of Wadi Safaja and Wadi Wasif, and in Sinaï in Jebel Safariat.

To the south of the Qena-Qosseir road, there is a large mass of limestone which is evidently the continuation of the Duwi range, at the base of which this bed in all probability occurs.

Bone-bed to the East of Qift.

Outcrop.

This bed is found on the top of a plateau called Jebel El Qurn, which lies at the junction of Wadi Matula and Wadi El Qurn, the combined drainage of which bears the name of either wadi, according as the guide is an Ababda or a Maazi.

From the plateau to the cultivation, a distance of 6 or 7 kilometres, there is a good road in the bed of the wadi, and afterwards across the cultivation to Qift station, a further distance of 3 kilometres, making the nearest point of the bone-bed in all 10 kilometres from the railway. From the furthest point of this plateau examined, the distance to Qift station is 20 or 21 kilometres. As there is no obstruction in the way, a light railway could be put down at a small cost, by which the phosphate could be brought down to the Nile with hardly any expenditure of power.

Extent of the
phosphate bed.

The plateau in which this bed occurs, measures between 1 and 2 kilometres at its greatest width, and is 9 to 10 kilometres long. At first it is triangular, but finally runs off in a south-easterly direction in a tongue of somewhat rectangular shape. This plateau is undoubtedly continued further on to the south, and in all probability exists behind that of the Eocene which lies on the east side of the valley, as patches of a phosphate bed were noticed in a traverse to the east of Esna, at which point, however, it was considerably more distant from the river, being at least 38 kilometres from the Nile. If the country to the east of the Eocene table-land were examined, it would possibly be found that the "Bone-bed" formed the top of a small subsidiary plateau at the foot of the limestone scarp, as in the Wadi Hammama.

In the plateau of Jebel El Qurn, the phosphate bed is well-marked by beds which underlie and overlie it. Beneath it comes a sandy limestone or calcareous sandstone, full of casts of *Artica Barroisi*, and *Trigonoarca multidentata*, while it is overlaid by a thin blue cherty limestone which forms large, flat, elliptical concretions. These two beds form never failing guides where the bone-bed happens to be obscured by rubble. Round the edges of the plateau, as well as where water-courses have begun to form, it has been removed by denudation. In the triangular patch previously mentioned, the surface is practically composed of the blue limestone more or less broken up, with the phosphate bed underneath. In some cases this bed forms the surface of the plateau, when it is in the form of rubble; while in others (and these are in a large majority) it is covered by rubbish which only in a few instances attains the thickness of 3.0 metres. As this is not in a hard, consolidated condition, its removal is not a difficult matter. Where the phosphate is broken up, screening and hand-picking may be necessary, but that is only a small item. Between the triangular patch, and the rectangular piece to the east of it, the bone-bed has been denuded away; and in this latter area itself, it occurs only in the ridges between the water-courses. As it is followed back to the south-east, it is seen to cover more ground, where in places it forms the surface, and can be scooped up in fragments without difficulty.

The thickness of the normal bed is nearly 1 metre, but the upper part of it has already undergone silicification. Chemical examination has shown that this does not affect the sample very injuriously, for in a highly siliceous specimen analysed there was a difference of about 7 % phosphoric anhydride between it and a normal sample. Even in the places where silicification has been carried to the greatest extent, 0.23 of a metre of good unaltered bone-bed is found, while it rises to 0.3, 0.45 and 0.6 metres in other places, the most common thickness being 0.45 metres.

From what was seen, it appears that the siliceous character of this bed is variable, but tends to increase towards the west.

During the examination of this plateau, several other bone-beds were noticed beneath the main phosphate layer, which detracts from their value, as the cost of extraction will be greater. From 3.2 to 3.6 metres below the main phosphate bed, there is a sandy limestone or calcareous sandstone which contains a good many scales and bones of fishes. In the middle there is a layer of 0.07 metres of very good material, but throughout the entire thickness of 0.76 to 0.91 metres there is a considerable quantity of phosphatic material present.

In a specimen from the normal "Bone-bed" examined in the Khedivial Laboratory, 22·5 % of P_2O_5 (phosphoric anhydride) was found which is equal to 49·11 % of tricalcic phosphate.

Confluence of Wadi Wasif and Wadi Safaja.

Phosphate-bearing beds occur also on the eastern slope of the Red Sea hills, in a faulted syncline at the confluence of the Wadis Wasif and Safaja, at a point 11 kilometres from the sea. Here the exposure is limited, being between 50 to 100 metres wide, and extending in all about 7 kilometres. There is a good road down Wadi Safaja to the sea, where there are 13 fathoms of water almost close to the shore.

In many places the phosphate bed is not well exposed, being covered with talus, but the following section measured in a water-course gives a good idea of the beds there present; the base of the section being the bone-bed :—

(Bottom) Bone-bed No. 1, containing fish-teeth, spines, and coprolites.....	1	metre thick.
(2) Flinty bed containing silicified coprolites.....	1	"
(3) Blue siliceous limestone, probably the same as that overlying the phosphate bed in Jebel El Qurn..	0·3	metres thick.
(4) Bone-bed No. 2, similar to No. 1.....	2·5	"
(5) Marly limestone and marls.,.....	7·7	"
(6) Baculite limestone, etc.....	1	metre thick.

The overlying beds were obscured by debris, but they were of a marly character.

From this section it will be seen that, although the phosphate beds are here much thicker, their value is considerably lessened by the great thickness of "overburden" which would have to be removed before they could be worked. Their position, too, is against them, as the cost of transport by sea and land would be a very large item.

As there seems to be a diversity of opinion as to the utility of these phosphate-bearing beds, the only way to decide the question is to carry out some experiments with the view of settling the matter. As the question has been ably discussed from the theoretical stand-point by Mr. A. Lucas in his report on the composition of different samples, it only remains to establish a few experimental plots, each side by side, treat them equally as regards the work of ploughing, breaking up, and preparing the soil, dressing the odd numbers with a fair quantity of ground phosphate, sowing all of them with seed of exactly the quality, and note the result for a few years. The only

expense in these experiments would be the setting up of a crushing machine and the working of the experimental plots. In this way it could be demonstrated to the fellah whether the addition of phosphates to the land is a profitable investment or not ; since he is very conservative in his ideas, the only way to convince him is to be able to point to what can be done in the old way without phosphates, and the result after their application. It is only by undertaking such experiments that their value can be demonstrated to landowners.

THOS. BARRON.

CHAPTER II.

PHOSPHATIC BEDS IN THE EASTERN DESERT, BETWEEN QENA AND QOSSEIR.

While geologically examining the Nile Valley to the south of Qena in the spring of 1897, Mr. Barron recognized a phosphatic rock in the immediate neighbourhood of Qift, though, owing to the faulted character of the ground, further generalization was at the time impossible. In the autumn of the same year, during a joint expedition made by Mr. Barron and the writer to the old mines of Aradia, on the return journey from the igneous hills a road was taken which cut through a low plateau running from south-west to north-east, parallel to a ridge connecting the limestone ranges of Serrai and Abu-Had. An examination of the rock exposed in the gullies and slopes on the eastern edge of this plateau led to the re-discovery of the phosphate bed, and the simultaneous finding of undoubted Cretaceous fossils in the overlying limestone, a key being thus provided which has enabled us to show that the phosphatic beds are in every instance intimately associated with strata of that age.

The exposure in question, which in a straight line is a little over 20 kilometres from Qena itself, is easily reached by the main camel road, which first goes up Wadi Qena and then follows the large branch of Wadi Um Sellimat to its head. Up to this point the track is of the easiest, but after crossing the ridge, the path descends somewhat steeply, though presenting no special difficulties even to loaded camels, and in its lower half passes through the Cretaceous beds (which form low cliffs on both sides), finally opening into the Hammama plain.

The plateau can also be reached by the still easier road, which going up Wadi Qena, passes up Wadi Gareya, this, without the intervention of any pass, leading direct into the Hammama plain. Thus, as far as roads and distance from an important centre are concerned, there are no insuperable difficulties to transport.

Turning now to the beds themselves, the typical succession and thickness are as follows:—

1. The summit of the plateau is formed by a hard, bluish, crystalline limestone, on whose weathered surfaces appear abundant specimens of Cretaceous Cephalopoda (*Ptychoceras*, etc.), and other fossils, this passing below into a less fossiliferous limestone. Total thickness, 0·45 metres.

2. Below this limestone is a lighter and more siliceous variety, very compact and of nodular aspect, in its upper layers containing fine casts of *Ptychoceras*, and alternating with chert beds, 1·2 metres thick.

3. A bone-bed, or more strictly a coprolite bed, partly siliceous, which on fracturing shews a number of rounded white fragments, fish-teeth and vertebrae, (*Lamna*, *Corax*, etc.). This layer, about 60 centimetres thick, is separated from another 30-centimetre bed by a band of siliceous limestone 30 centimetres thick, while the lower bone-bed is separated by a green marl 15 centimetres thick from—

4. Oyster limestone, 1·2 metres thick.

It will thus be seen that the overburden to be dealt with is a hard limestone about 2 metres thick, the problem being whether this can be wedged off, or whether the phosphate bed will have to be cut out from underneath, pillars being left. In the numerous faulted portions, the first method may be found possible, as the upper limestone is much cracked. Owing to the phosphate and oyster beds being softer than those overlying them, the latter overhang in many places. The best method of treating the overburden will probably have to be determined on the spot by experiment.

The proved area mapped by Mr. Green in which the Cretaceous beds are known to exist, extends over a length of 25 kilometres from the base of Jebel Serrai to the southern edge of Jebel Abu-Had, with an average breadth of over a kilometre. It cannot, however, be absolutely said, that the whole 25 square kilometres are occupied by phosphate beds, because of the disturbance by faulting, but that within that space deposits of this nature are of common occurrence.

Thus, though the Cretaceous plateau has been breached by Wadi Hammama where it joins Gareya, from this point it becomes more and more marked to the north, until at the foot of Jebel Abu-Had it forms a vertical cliff over 40 metres high, capped by yellow outliers of Eocene limestone. The summit of the plateau is determined by the *Ptychoceras* limestone, beneath which is a bone-bed, and over 30 metres of green shales, but in addition at its base is a second bone-bed, containing teeth of *Lamna*, etc.

The plateau itself, following the dip-slope of the beds (about 4° NW) rapidly sinks into the El Nagateir plain to the northward, and although two traverses have been made to the north of this point, it has not again been struck, so that the southern end of Abu-Had must be considered as the northern limit of the extension of the phosphate beds.

Probably as the result of faulting, fossil-bearing Cretaceous strata

form the surface of a low broken plateau at the foot of the main cliff, the summit of these ridges being in some places crowded with the remains of *Baculites* poorly preserved. Immediately underlying this layer is a bone-bed containing oysters, teeth of *Lamna* and *Corax*, coprolites over $2\frac{1}{2}$ centimetres in length, abundant vertebræ, and at the junction with the underlying marls, large bone fragments; most of the latter from a theoretical stand-point are unfortunately in a very brittle condition, though from the practical point of view this would be an advantage. The Abu-Had lower plateaux, though further from Qena, therefore claim attention on account of the absence of a hard covering-layer, and the greater size of the remains to which their phosphatic character is due.

If the northern distribution of these deposits has thus been determined, their southern extension is at present unknown, Mr. Barron's discovery at Esna being the last record of their occurrence in this direction. But in a recent journey from Luxor to Assuan, the fact impressed itself upon my mind that the Cretaceous beds must have a very wide extension between Luxor and the great plain north of Daraw, the Eocene outliers disappearing and being replaced by a series of lower plateaux, which both in position and character recall the strata under discussion. If these should prove to be also phosphate-bearing, it may then be stated that the supply of low-grade Egyptian phosphate is inexhaustible; and if experiment should show it to be commercially valuable, the proximity of these beds to the railway would be of high importance. (NOTE,—In passing, the station of Matama seemed to me to be a good centre for starting further examination, when required.)

Thus it will be seen that, as far as is known at present, phosphate beds form part of the Cretaceous series wherever examined on the eastern side of the Nile Valley, and the latter extends from the southern end of Abu-Had, possibly as far as the Daraw plain, the distance between it and the Nile Valley or railway gradually diminishing from over 20 kilometres to nothing. Faulting, too, as in the case of Wadi Matula near Qift, may expose these strata at points where otherwise in the normal succession they would not be expected.

Character of the Phosphates.

Hitherto the distribution of the phosphate-bearing deposits has alone been considered, but the question of composition is obviously of prime importance in the discussion. Unfortunately, this question cannot be as yet considered in full, as the Eastern Desert analyses are not completed.

Still, the analysis of the Wadi Matula specimen, and comparison with those from the neighbouring regions shows that the probable average will be from 20% to 25% of phosphoric acid (P_2O_5 really), or in other words a rough average of from 40% to 50% of tricalcic phosphate. Any question of export is thus practically excluded, as may be gathered from the following extract of a letter with which I have been favoured by Mr. J. C. Winkfield, of the firm of Pickford and Winkfield, a leading authority on the value of phosphates. “At the present time you are probably aware there is a very abundant supply of all classes of phosphate of lime ranging from the low grade 40% Belgian up to high quality Florida, testing as much as 78·80%; to-day the value of the highest grade phosphate is about 6*l.* per unit per ton of phosphate of lime, which after deducting freight, inland and other charges, does not leave the miner more than about 12*s.* per ton net at the mines.

“Nothing is so disappointing and unsatisfactory as phosphate mining, because as you are no doubt aware, the deposits are more or less pockety, require very careful handling, and are in many cases costly to work. In addition to this, the buyers insist upon very stringent guarantees, both as regards the percentage of phosphate of lime, as well as oxide of iron and alumina. In selling high class phosphate, a minimum guarantee of 78% phosphate of lime, being the equivalent of 35·75% phosphoric acid, and a maximum of 3% oxide of iron and alumina has to be given, and when the quality falls below 78% or above 3%, absolute rejection of the cargo is made. For your guidance, I enclose copies of analyses of a good and bad cargo of Florida. In the one case you will notice the phosphate of lime runs as high as 79·03% with 2·26% oxide of iron and alumina, in the other, only 75·16% phosphate with 5·43% iron and alumina. Such a quality as this is absolutely unsaleable.

“Besides the above standard, a good low class phosphate of lime is very easily disposed of containing from 56 to 63%. Outside phosphate of lime, there is also a moderate demand for phosphate of alumina.”

In the *Manufacturer's Record*, July 29, 1898, pp. 4-5, a large series of analyses are given, which will serve as terms of comparison. Some selected types are given below:—

	Hard Rock Florida.	Florida River Pebble.
Phosphoric Acid.....	36·73	27·91
Iron Oxide.....	·70	2·57
Alumina.....	1·63	—
Bone Phosphate	80·18	60·93

	High grade Algerian Phosphate.	Phosphate from Somme (France).
Moisture	3.00	2.00
Bone Phosphate	64.88	78.50
Phosphoric Acid.....	29.76	35.70
Alumina.....	0.31	0.70
Oxide of Iron	0.24	1.40
Lime.....	50.68	—

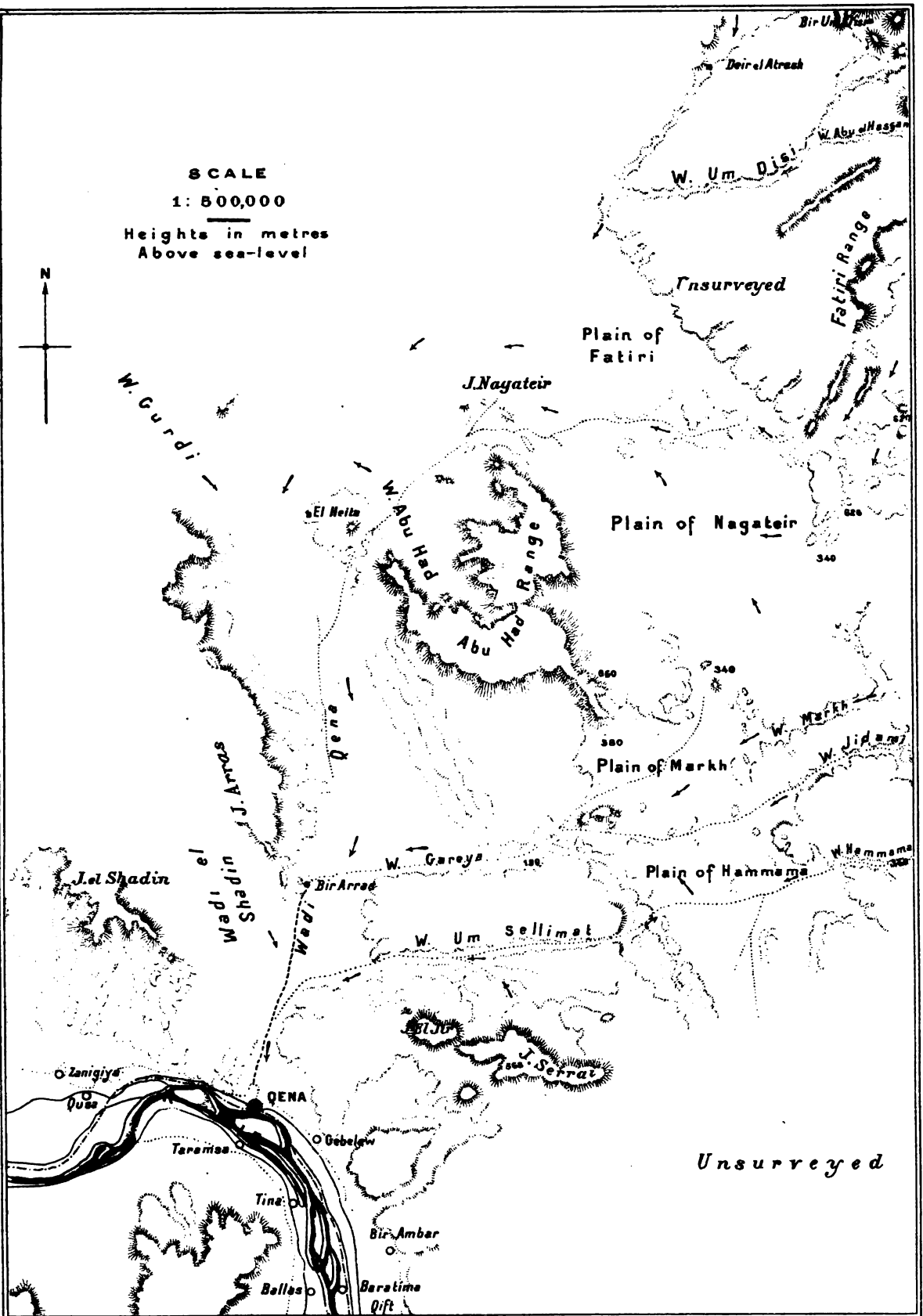
	South Carolina Phosphate.	Belgian Phosphate.
Moisture	0.5 to 4.0	0.25
Phosphoric Acid	26.0 „ 29.0	20.59
Iron Oxide	1.0 „ 3.0	18.64
Al ₂ O ₃	trace „ 2.0	—
Bone Phosphate.....	57.0 „ 63.0	45.30

Egyptian (Eastern Desert) phosphate 22.5 % phosphoric acid.

As far, therefore, as present analysis goes, the Egyptian variety is somewhat inferior to the Carolina and superior to the Belgian. The question of export does not arise, seeing that Egypt as an almost exclusively agricultural country, could take any available supply. The point to note here is, that Egypt possesses an apparently unlimited supply of low grade phosphate within easy reach of the Nile Valley. How far it may be worth working can only be determined by experiment.

PHOSPHATES IN THE EASTERN RED SEA HILLS.

On the road from Qena to Qosseir, a little south of the latter town, is the very conspicuous range of Duwi, which owes its origin to faulting, having let down limestones of Eocene and Cretaceous age against older rocks. While the main crest is formed of the Eocene limestone, it is flanked on the south by a lower plateau of Cretaceous limestone, which is separated from Wadi Abu Zeran by low hills of brown-red Nubian sandstone. It is interesting to find that in this series the bone-bed reappears, containing fragments of bone and vertebræ, coprolites and teeth of *Lamna*, etc., the whole bed, which is overlaid by thick limestones, being itself about 0.45 to 0.6 metres thick, and having undergone a certain amount of silicification. Although near a small sea-port, its position is otherwise not very favourable from an economic standing-point, though of theoretical interest. Similarly, at the western end of the Duwi range, in Wadi Saga, the Cretaceous beds rise from underneath the Tertiaries at a point where



it suddenly narrows from a wide plain to a narrow ravine; they consist mainly of bone-beds and cherty layers, closely associated and alternating, and of greater thickness than had previously been observed. In the Saga plain itself run two ridges, curving round in a semi-circle, the one towards the Duwi range consisting of the bone-beds dipping at an angle of 20° . As far as has been at present noted, bone-beds are only present in the Cretaceous series south of latitude 27° north., as the limestones of that age examined in the Mellaha limestone range parallel to Jebel Esh only contained bone fragments, and no true phosphatic layers.

W. F. HUME.

CHAPTER III.

THE PHOSPHATIC BEDS OF DAKHLA OASIS.

The existence of thick bone-beds in the lower part of the great Cretaceous escarpment to the north of Dakhla Oasis, was first noticed in February, 1898, and during the geological survey of this area in the following months, the exact extent and development of these beds was mapped and examined.

Prof. Zittel, who geologically examined this oasis in 1874, during the progress of the Rohlf's Expedition, mentions brecciated beds containing fish teeth, as occurring in the lower beds of the Cretaceous series. These doubtless are identical with the bone-beds now to be described, which probably were poorly developed at the points examined by Zittel, as they do not seem to have been recognized by him as true bone-beds, or as of any economic importance.

Outcrop.

The bone-beds occur throughout the oasis, stretching from the extreme west at Qasr Dakhla to the extreme east at Tenida, a distance of over 50 kilometres. They, and the beds which occur in association with them, occupy the entire area between the main cliff, or wall, of the oasis and the northern limit of the cultivation on the low ground, a breadth varying from 3 to 6 kilometres. The total area of outcrop is thus roughly something like 200 or 250 square kilometres. The bone-beds, together with their associated clays and sandstones, form in fact a low subsidiary plateau, between the main cliff and the cultivated lands, the surface of which has a well marked dip slope of 2° or 3° to the north. The escarpment of this plateau, facing the low cultivated ground, is very irregular and frequently cut up into numerous indentations separated by promontories, so that its distance from the cultivated lands and villages varies considerably; whereas in the districts of Qasr Dakhla, Birbaya, Budkhulu, Rashida, Hindaw and Smint this escarpment is usually contiguous to the cultivation, between Smint and Belat, and beyond the latter to the west, it recedes and keeps much nearer to the main cliff; at Tenida it is however quite close, in places actually abutting on the cultivated land.

The bone-beds, with the exception of a small patch, are not found in the desert to the south of the cultivation.

The extension of these beds to the east and west of Dakhla is not known with any certainty. To the west, however, if they do not altogether die out, they become of much less importance. Between

Dakhla and Kharga they occur in all probability to some extent, although their outcrop has not been followed; the latter, if the beds are developed, would be found near the base of the prominent cliff which runs between the two oases. No trace of these beds was seen on the Derb El Gubari, the lower road from Dakhla to Kharga, which keeps at a considerable distance from the above-mentioned cliff.

From the detailed sections published in the "*Report on the Geology of Dakhla Oasis*," it will be seen that there are usually several distinct bands, separated by intervening beds of clay, sandstone, etc. The following is a typical section of the escarpment, and was measured one kilometre south-east of Rashida.

TOP OF ESCARPMENT.

	Thickness in metres.
1. Hard brown, more or less crystalline, limestone passing in places into white chalk.....	0·65
2. Blue laminated clays	2·50
3. Brown, rather friable, coprolitic fish-bone bed.....	0·65
4. Grey marly shales, and brown sandy clays.....	3·00
5. Light brown coprolitic phosphatic bed (Sample O).....	0·30
6. White phosphatic bed (5 cent.) with hard white shaly clay.....	0·30
7. Brown sandy clays.....	2·00
8. Very coarse, brown coprolitic fish-bone beds, with numerous teeth (Sample N).....	0·65
9. Clays, sandy clays and sandstones	6·50
10. Hard white phosphatic bed (Sample M).....	0·25
11. Slaty blue laminated clays, with a few white bands.....	4·50
12. Brown, coarse, sandy, gritty bed, with a certain quantity of fish remains	0·65
13. Hard brown sandy limestone with casts of shells.....	0·65
14. Dark green sandy clays, slaty blue laminated clays, with thin veins and beds of gypsum.....	7·50
15. Alternating light green clays and brown sandstone. Thin veins of gypsum, opaque white and dehydrated on surface. Black carbonaceous matter and obscure plant remains are seen in some of the sandy beds. Beds of hard dark silicified, concretionary weathering sandstone occurs near base.....	15·00
16. Red clay, often marly, and green ($\frac{1}{2}$ metre) at top.....	7·50
BASE AT CULTIVATION LEVEL.	52·60

It will be seen that at this point the phosphatic bands form five different layers, with a total thickness of about $2\frac{1}{2}$ metres. The follow-

ing table shews the approximate total thickness of bone-bed at the several places where sections were measured:—

Qasr Dakhla.....	3 metres.
$\frac{3}{4}$ kilometre NE of Birbaya	1 ..
At village of Birbaya	2.5 ..
2 kilometres E of Rashida.....	1.2 ..
1 kilometre SE of Rashida.....	2.5 ..
Ain El Sabil, 3 kilometres NNE of Hindaw.....	2.5 ..
Tenida.....	2 ..

The average thickness of bone-bed is therefore usually between two and three metres. The different bands do not remain constant over large areas, but vary from point to point in thickness, distance from each other, etc.; but the beds taken as a whole are fairly constant in character. The colour is usually dark brown, but a notable exception is formed by the less frequently occurring compact white bands. The rock varies a good deal in compactness, at times being very hard compact and difficult to break, or again becoming soft and friable. The beds are almost entirely composed of fish remains, chief among which appear to be coprolites, together with broken up bones, including occasional vertebræ and numerous fish teeth of the genera *Lamna*, *Otodus*, etc. Probably coprolites form the bulk of the mass.

Exploitation.

Throughout the desert margin bordering the cultivated lands of Qasr Dakhla, Birbaya, Rashida and Hindaw, these beds could be worked with great facility. At Smint also the outcrop is at no great distance from the village. Little could be done between Smint and Belat or at the latter place, but at Tenida a fair extent occurs in close proximity to the village.

At the first four villages named the supply would be very considerable even if the beds were only worked along their outcrops on the escarpment. Later on, when further developed, the overburden to be removed would not exceed a metre or two, and the output obtainable is practically unlimited. But probably the supply would suffice for a considerable time if the bone-beds were simply worked where they are exposed along the cliff face, without removing any overlying material whatever.

Analyses.

Thirteen samples from different localities were selected for analysis and the results obtained for six of these are shown in the table below; the remainder have not yet been examined, but in all probability would not vary in any great degree from those now given.

The six specimens analysed represent very fairly the variation in

quality of the different bands, as they were selected from what appeared in hand specimens to be the different varieties occurring.

In all probability by working only the highest grade bands the percentage of tricalcium phosphate could very easily be kept up to between 55 and 60 per cent. If all the bands were worked indiscriminately together the average would probably be from 40 to 50 per cent. In each locality there is as a rule at least one good band, which is usually also the thickest; the thinner bands, which point to less favourable conditions for the development and multiplication of the fish which swarmed at the time of the deposition of these beds, are usually the poorest in quality, in percentage of phosphoric anhydride, and in freedom from enclosed sand and clay.

The analyses shew that the richest bands are almost equal to the best Carolina phosphates, and do not compare unfavourably even with the fine Florida deposits.

It is clear therefore that the material occurs in sufficient quantity, ^{Transport, etc.} and has a sufficiently high percentage of phosphoric anhydride, to render it of the greatest economic value, especially to an agricultural country. It occurs moreover in such a position as to render its exploitation extremely easy. The only consideration therefore is the important one of transport.

If worked solely for the use of the oasis itself, there is no question of transport at all, the material being on the spot. It is probable that great benefit would result to the land from the use of a phosphatic fertilizer as the soil is becoming poorer every year; the only manure it receives being a very small amount of various salts, of doubtful fertilizing value, deposited from the water of the springs used in irrigation, and probably a certain amount of phosphatic dust, derived from the denudation of the exposed bone-beds along the escarpment, blown and deposited by the north winds on the cultivated lands. The amount of phosphatic material thus received is unknown, but it is quite possible that this is the cause of the fine quality of some of the soil of Qasr Dakhla, Rashida, etc.

Whether it would pay to erect plant in Dakhla for crushing, washing, drying, and converting to superphosphate is doubtful, but this would not probably in any case be undertaken at the outset. Inexpensive grinding mills of some sort, either worked by hand or wind power, could however easily be provided.

As at some future time, when the value of these beds is more fully appreciated, the question of the transport of the material, either in its ^{Transport to Nile Valley.} native state or after conversion into superphosphate, to the Nile Valley

may be raised, it will be well to say a word or two as to the intervening country. From Dakhla to Kharga the desert is fairly level and the construction of a light railway would not present any very great difficulties. The distance to be traversed without water would be about 135 kilometres.

Water is available in plenty in Kharga.

Between Kharga and the Nile Valley, near Erment, lies a high plateau, which itself would present no difficulties to the construction of a light railway, except that no water is available. The ascent from Kharga to this plateau, a height of some 300 or 400 metres would necessitate the construction of an inclined plane system of some magnitude. The descent of the cliffs to the Nile Valley would be one of comparative ease.

The only other transport available is by camel, which is largely used for the export of dates, the journey from Dakhla to the Nile Valley taking from 7 to 8 days.

Analysis of Dakhla Bone-beds (By A. LUCAS).

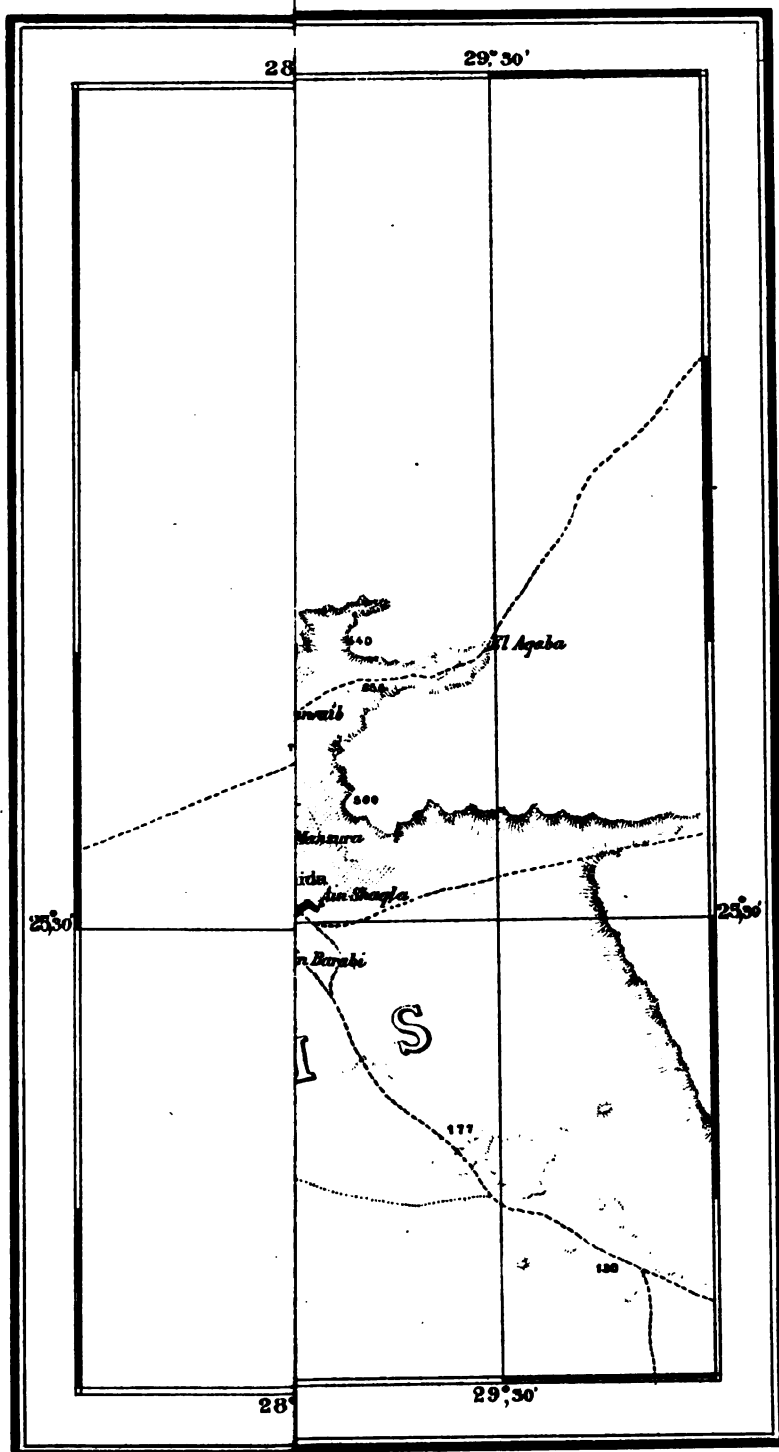
SAMPLES	LOCALITY	Phosphoric Anhydride P_2O_5 %	Tricalcium Phosphate $(Ca_3(PO_4)_2)$ %	DESCRIPTION OF BEDS
E	Qasr Dakhla	27.93	60.97	Coarse brown coprolitic bone-bed.
N	Rashida.....	25.88	56.50	Very coarse brown gritty phosphatic bed, full of bones, teeth, and coprolites.
G	Birbaya	21.43	46.78	White gritty phosphatic bed.
Q	Hindaw.....	20.89	45.60	Hard brown compact coarse brecciated bone-bed.
M	Rashida.....	16.21	35.37	Hard white phosphatic bed.
H	Birbaya	12.29	26.82	White calcareous phosphatic bed.

Baharia Oasis.

Other localities
on W side of
Nile.

In this oasis the Cretaceous bone-beds are represented by a single thin band, found at various points both in the hills within the depression and on the western escarpment. The band is highly siliceous and

PLATE III.



the rock very hard and compact. From its siliceous character, and slight development, this bed may be regarded as of little or no economic importance.

The following is an analysis of this band:—

Phosphoric Anhydride.....	11.49 %
Equivalent to	
Tricalcium Phosphate.....	25.09 %

Nile Valley.

The bone-beds which have been found by Mr. Barron on the east side of the Nile valley in the neighbourhood of Esna, in all probability are repeated, at the same horizon, on the western side. Between Esna and Qena however, on the left bank of the cultivation, no bone-beds were found, the base of the Esna shales, below which the bone-bed series lies, not being exposed. To the south of Esna, however, where the Cretaceous must come to the surface, it is almost certain that the bone-beds will be found to occur, and they will not in all probability greatly differ from those on the eastern side. This area, however, has not yet been examined or mapped.

H. J. L. BEADNELL.

CHAPTER IV.

CHEMICAL REPORT ON THE PHOSPHATES.

During the course of the recent Geological Survey of Egypt extensive phosphate deposits have been discovered: some of these deposits are situated in the north in the peninsula of Sinai, some are in the south in the oasis of Dakhla, while others lie between the two and are found in Baharia and in the eastern desert near Qena.

These phosphate beds, which range in colour from a light grey to a yellowish brown, are composed for the most part of fossil bones, such as the vertebræ and teeth of fishes, together with coprolites and varying quantities of siliceous matter, carbonate of lime, and iron and aluminium oxides.

At present the whole of the samples taken have not yet been examined, but those already analysed give the following results:—

PLACE OF ORIGIN.	Phosphoric Acid (P_2O_5) %	Tricalcium Phosphate $Ca_3(PO_4)_2$ %
Sinai.....	5.93	12.94
Sinai.....	22.19	48.44
Baharia.....	11.49	25.09
Dakhla.....	27.95	60.97
	21.43	46.78
	12.29	26.82
	20.89	45.60
	25.88	56.80
	16.21	35.37

It will be seen that the samples are not all of equal value, the percentage of tricalcium phosphate varying from 12.94 to 60.97.

Before comparing these Egyptian phosphates with phosphates from other sources, it will be well to consider first the elementary question of the need of phosphates at all in agriculture.

The element phosphorus in the form of one or other of its compounds is most widespread in nature, and is essential to the building up of all animal and vegetable bodies. It is the characteristic ingredient of seeds, and forms about 50 per cent of the mineral matter of the

grains of the different cereals, besides occurring in all fruits and vegetables. The following tabular statement will make this clear:—

PLANT (ASH OF).	Phosphoric Acid (P_2O_5) %	AUTHORITY.
Wheat Grain.....	52·8	{ LAWES AND GILBERT. <i>Journal, Chemical Society, 1884.</i>
" "	46·3	
Barley Grain.....	33·1	{ MACKENZIE AND FOADEN, <i>Manures in Egypt.</i>
Maize Grain.....	44·8	
Cotton Seed.....	31·1	{ DR. A. B. GRIFFITHS, <i>Journal, Chemical Society, 1883-7.</i>
Sugar-Cane.....	4·8	
Bean	38·8	
Turnip	16·4	
Potato	15·6	
Cabbage.....	13·6	

Since plants derive the greater part of their nourishment from the soil in which they live, it follows that phosphoric acid is essential to a fruitful soil, in fact in a soil destitute of phosphorus no plant could grow however well supplied it might be with other food substances.

The amount usually present is however only small, a moderately fertile soil containing about 0·3 per cent, and, since all crops remove phosphoric acid to a greater or lesser extent, the supply must be renewed from time to time or the soil will become exhausted.

In nature the phosphorus taken from the soil is returned to it when the plants decay and the animals die, but in agriculture the vegetable and animal produce are consumed off the land, and hence to retain its fertility we have recourse to manuring.

Manures are essentially of two kinds, natural and artificial.

Natural, or farmyard manure, can never by itself be sufficient to restore to the land the phosphorus removed by the crops, since it only contains this element in small quantities. According to analyses made by the late Dr. A. Vœlcker, F. R. S., farmyard manures contain from 65 to 80 per cent of water and from 5 to 8 per cent of ash, and of this ash only 0·3 to 0·5 per cent is phosphoric acid.

Hence artificial manures containing phosphorus must be used.

This fact has long been recognized in Europe where immense quantities of special phosphatic manures are annually placed on the land.

In Egypt the same conditions exist as in Europe. The soil is very similar in composition and contains on an average 0·28 per cent of

phosphoric acid (*Manures in Egypt*; by MACKENZIE and FOADEN) and the crops, as will be seen from the table previously given, all require considerable amounts of phosphorus. Hence in Egypt as in Europe the supply of phosphoric acid must be constantly renewed if the soil is to be kept fertile.

Since in Europe farmyard manure is never by itself sufficient to restore to the land the phosphorus withdrawn from it by the crops, it follows that in Egypt this is still more the case because the proportion of such manure available is very much less owing to a large part of it being used for fuel and the ashes wasted.

In Egypt however two sources of phosphoric acid are available that do not exist elsewhere namely Sebakh Qufri and the Nile mud.

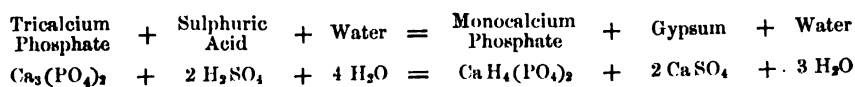
The former contains on an average 0.72 per cent of phosphoric acid (*Manures in Egypt*, by MACKENZIE and FOADEN); while the latter contains at most about 0.25 per cent.

Concerning the phosphoric acid content of Nile mud there seems some difference of opinion.

In the two samples mentioned by Horner (*Alluvial Land of Egypt*) and analysed in London under the superintendence of Dr. Hofmann, there was no phosphoric acid. In some analyses of Sickenberger again no mention is made of phosphoric acid, while Mackenzie and Foaden (*Manures in Egypt*) give 0.32 per cent and Parodi (*Les Engrais en Égypte*) gives 0.24 per cent.

In any case however neither Sebakh Qufri nor Nile mud contain sufficient phosphoric acid to balance the great and increasing quantity annually removed from the land, the three-quarters per cent in the former and the one quarter per cent in the latter becoming the merest traces when calculated as a percentage of the soil over which the sebakh or the mud is spread. Hence artificial phosphatic manures are also needed in Egypt.

The utilization of crystalline and fossil phosphate by treatment with sulphuric acid was the work of Lawes and was patented by him in 1842: it was however merely the outcome of Liebig's suggestion in 1840 to render bones soluble in a similar way. This reaction of sulphuric acid upon tricalcium phosphate is, in its simplest form, as follows:—



That is, tricalcium phosphate, which is insoluble in water, under the influence of sulphuric acid becomes monocalcium phosphate, which is soluble.

Not only however is the tricalcium phosphate acted upon by the sulphuric acid, but most of the other substances that are present, such as carbonate of lime, iron and aluminium oxides, etc., are acted upon at the same time. Hence the greater the percentage of foreign matter in the phosphate the greater must be the amount of sulphuric acid used, and the greater the cost of manufacture.

Thus the amount of phosphate present in a phosphatic mineral determines in a large measure its value, though this value is also to some extent conditioned by the manner in which the phosphoric acid is combined, minerals rich in phosphoric acid combined with iron and aluminium being practically useless to the manufacturer of superphosphate. This is because iron and aluminium phosphates, being only soluble in the presence of much free acid, remain unacted upon and insoluble. Also, if the iron and aluminium be present as oxides, the case is much the same, since no sooner is the sulphuric acid added than these oxides combine with a portion of the phosphoric acid which would otherwise become soluble and retain it in the form insoluble phosphates.

If, however, the iron is in the form of pyrites or silicate it has probably little or no action and is comparatively harmless.

Sand is the most innocent of all the useless ingredients in a mineral phosphate; it consumes no acid, it does not reduce the soluble phosphate, it is simply inert.

A small amount of carbonate of lime is useful, since, although it uses up sulphuric acid, the evolution of carbon dioxide that necessarily takes place insures a light porous texture in the manure, and the extra quantity of gypsum formed increases the dryness of the product.

A comparison may now be made between the recently discovered native phosphates and those used in Europe for the manufacture of superphosphate.

The mineral phosphates used for this purpose range from the ordinary grade Belgian containing 18·9 per cent of phosphoric acid (equal to 41·3 per cent tricalcium phosphate) to the good class West Indian which contains 40·2 per cent of phosphoric acid (equal to 87·8 per cent tricalcium phosphate)—vide *Dictionary of Applied Chemistry*, by THORPE.

About 40 per cent tricalcium phosphate is therefore the lowest limit for the successful manufacture of superphosphate, and this only produces a second rate article, the first qualities being made from phosphates containing from 60 to 80 per cent of tricalcium phosphate.

Thus it will be seen that the quality of the Egyptian phosphates, even assuming their freedom from much iron or aluminium, is not

on the whole sufficiently good to warrant the idea that any successful manufactory of superphosphates could be established in Egypt, nor, unless some of the other samples are much richer than those analysed, is it likely than any market could be found in Europe to which it would pay to export them.

The conversion of these native phosphates into superphosphate being then probably out of the question, there still remains to be considered whether it is possible to utilize them in their natural state, and whether mineral phosphates in their raw condition are of any value as manure.

It is manifest that all plant food before it can be assimilated must be brought into such a condition that it can readily pass by absorption into the root hairs, that is, it must be rendered soluble.

Since tricalcium phosphate is insoluble in water it would appear at first sight to be quite useless as a plant food.

Any such hasty conclusion however would be erroneous, for most forms of water-insoluble phosphate (certain crystalline mineral phosphates excepted) are largely soluble in weak acid solutions, and the acid sap of the root hairs as well as the carbonic acid and the humic acid in the soil act upon insoluble phosphate and render it soluble and available for plant life.

This being the case it will naturally be asked wherein then lies the superiority of superphosphate and what is the necessity for going to the expense and trouble of rendering the insoluble form soluble when this conversion will take place in the soil?

Superphosphates however give quicker if not better results, though this is not, as is so often stated, because they are at once absorbed by the crops.

It is true that when placed on the land the superphosphate is soluble and in a condition to be immediately absorbed, but, no sooner does it come in contact with the carbonate of lime and the oxides of iron and aluminium in the soil than part at any rate is once more rendered insoluble, though not in the hard dense form in which it previously existed but in a new form more readily acted upon by acid solutions.

Herein then consists the superiority of superphosphate, namely that a portion can be at once absorbed by the plants and that the rest, though actually it becomes insoluble, yet is in a form easily acted upon and again rendered soluble, and further that before any part is converted into the insoluble form there is time for it all to be diffused throughout the soil in a manner impossible to effect by merely mixing in.

To acknowledge the general superiority of soluble phosphates is not to confess that the insoluble form is useless, for such is not the case. The majority of mineral phosphates are very effective as manure when used in their natural state, provided they are finely ground, but this effectiveness varies on different soils. The soils most suitable for such manures are those rich in humus and poor in carbonate of lime, these being the conditions (presence of humic and free carbonic acid) most favourable to the solution of tricalcium phosphate.

The native phosphates will be useful to all classes of Egyptian agriculturists. They will be useful to the Fellahin and small farmers who know nothing of superphosphates, nor would be able to pay for them if they did, for to these classes the choice is not between an imported soluble phosphate and a native insoluble phosphate, but between this latter and none at all.

They will be useful also to those who do know and can appreciate the difference between a soluble and an insoluble phosphate, but whose conditions of work are such as to make the cost of imported manures prohibitive, and for whom it is no longer a question as to which of the two gives better results, but whether it is not wiser to use what lies at their feet rather than to allow their land to become impoverished.

And to the large landowners the native product will be of value in supplementing the imported and high priced article. I am strongly of opinion therefore that these recently discovered phosphates ought to prove of great value to Egyptian agriculture, for the following reasons:—

- (1) They occur in immense quantities.
- (2) With the exception of those found in Sinai and Dakhla they are easy of access and fairly close to the river and railway.
- (3) By means of a very inexpensive operation, namely, simple grinding, they can be prepared ready for use.
- (4) They constitute a really valuable and cheap manure of a kind that is much needed.
- (5) No other phosphatic manure of similar value exists in the country and the price of imported phosphate manures is such as to render them in many cases prohibitive.

A. LUCAS.

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